# Increasing the Efficiency and Availability

## Solutions for Smaller and Medium-Sized Power Producers

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steag

# Tried and Tested Technologies – Now Also for Smaller and Medium-Sized Power Producers

Expert systems are in great demand. In the light of rising energy costs, decreasing raw material resources, and the worldwide increase in $CO_2$ emissions, the topic of energy efficiency is becoming more and more important. Moreover, the increased generation of electricity from renewable sources is leading to additional requirements regarding the flexibility, minimum load, and availability of the conventional power plant installations. In recent years, these changes in the field have prompted operators of large power plant units to use expert systems for analyzing and optimizing the power generation process on a large scale. System Technologies now also provides smaller and medium-sized power producers with these tried and tested technologies – specially tailored to their needs.

For more than 20 years, the division System Technologies of STEAG Energy Services GmbH has been developing and supplying professional IT solutions for the monitoring and optimization of power plants. The systems used in STEAG's own power plants significantly contribute to the fact that both the efficiency of the plants and their availability are lastingly on a high level. The field-tested solutions also improve the operation management of the technical plants, among other things by detecting early on when the behavior of a component is changing, and by keeping the staff members who are authorized to access up to date with relevant technical information and analysis data at all times.

**Energy management systems by System Technologies**

The energy management systems by System Technologies allow to monitor, check, and optimize the essential technical and economic coherences regarding the supply of energy. Specifically, among these are solutions for supporting the operator

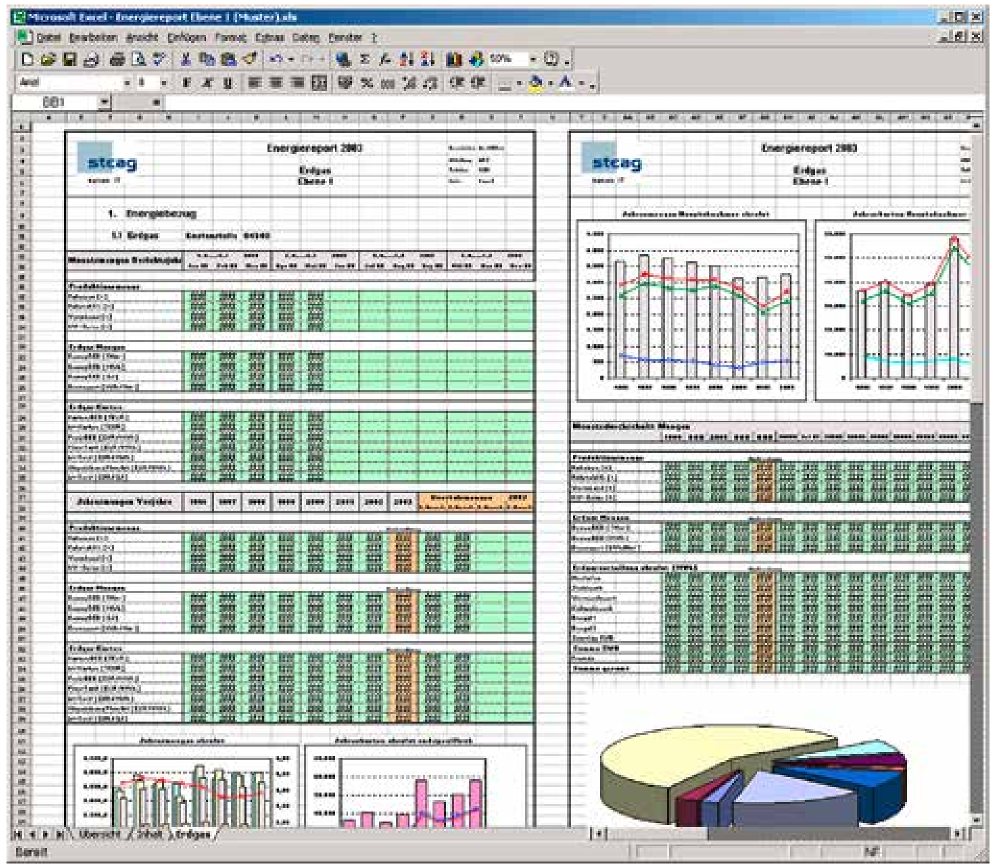
- in continuously analyzing the power generation process, so that possible deviations from the current reference condition are quickly detected
- in continuously monitoring the so-called key performance indicators to detect significant changes of components or process parameters
- in analyzing technical data, so that all involved staff members can be provided with relevant information quickly and in an uncomplicated way
- with combustion optimization and furnace operation control respectively at waste incineration plants, as well as
- with an innovative closed loop control of SNCR plants for NOx reduction.

The basis of all projects is a detailed analysis of the technical processes and their modeling in the respective system environment. Subsequently, the scope of supply comprises the installation, commissioning, and acceptance tests, just as the training of the customer's staff. The systems for energy management help to reduce the consumption and thus the operating costs.

# Process transparency and efficient reporting

# Saving, Visualizing, and Conveying Data with SR::x

- Providing validated measured values
- Continuous buildup of a complete data history
- Visualization and identification of off-limit conditions
- Creating technical reports at the push of a button



Creating any reports at will using the Excel add-in

### Commercial and technical challenges

Control systems of power plants are primarily designed for plant control and safety, respectively. In most of the systems, the significant data of the process are highly scattered and can only be reached with a lot of clicks in the control room. These data are not only hard to find, but usually only represent the current status and can be viewed neither in a temporal relation nor in a comparative context to other process data. In contrast, the data server SR::x by System Technologies allows for a modern and comfortable observation of all process data, also in their history. This way it helps provide plant operators and their operational staff with a high process transparency and allows for a fast and individually adjustable reporting. Besides shorter response times to the transgression of limits, SR::x reduces expenditures of time for the targeted and precise information of management.

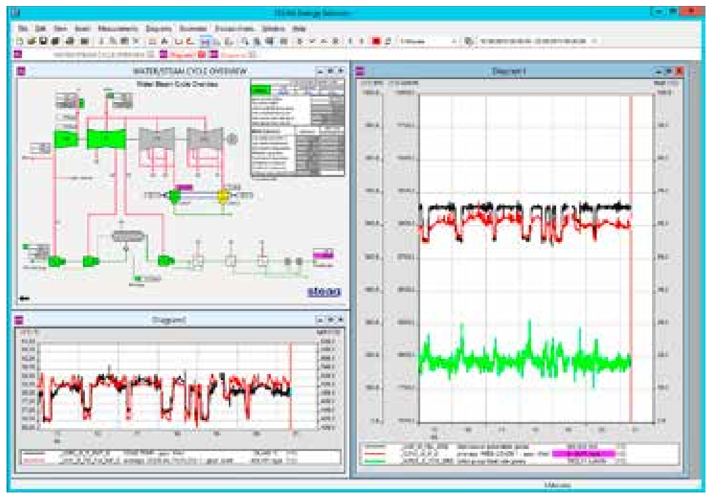
### The method of operation of SR::x – an overview

The data management system SR::x is the central data archive of the SR product range. Operational data are periodically extracted from control systems and other source systems, transferred into the data management system, and archived in the form of time series. The data are automatically condensed into higher time classes (e.g. from one minute to a quarter, an hour, a day, a month, etc.). User-friendly tools are available for evaluating the data. The availability of the data history is only limited by the hard disk capacity of the server.

### The most important features of the monitoring suite

### Data visualization with SR::Vis

The comfortable data visualization SR::Vis enables the representation of time series in diagrams as well as the representation of operational data and/or calculation results of a point in time in process images. Data points can be inserted by drag and drop directly from a process image into a diagram. All data points available in the system can be reached via a corresponding selection dialog. Time series of different data points can be represented on several ordinates. Besides the chronological display as line graph or bar chart, organized load curves or X/Y diagrams are available as well.



Visualization of the data in the process image and diagram

The position of the cursor in a diagram automatically synchronizes the currently displayed point in time in all process images and diagrams. This way, specific points in time can be displayed very easily and comfortably.

Special events, e.g. off-limit conditions, can be indicated in process images by automatically flashing texts or by means of color changes. The displayed data of the visualization is immediately available for further evaluation with other programs via the clipboard (copy and paste).

### SR::Studio

The SR::x system is configured using SR::Studio. This module allows the user to access configuration settings, so that it is possible to create further data points (among other things). In addition, SR::x contains a mathematical editor with extensive functions for compiling formulae. Depending on the task, existing data points can be linked this way. For thermodynamic calculations, SR::x provides the current water/steam table.

### The interface SR::xInterface

The measured values from the control system are taken over periodically as one-minute values from the control system or from other sources of data (e.g. PI Server) via SR::xInterface. All common DCS interconnections are supported.

### The Excel add-in SR::xExcel

The Excel add-in SR::xExcel provides data from SR::x in freely configurable report sheets on an Excel basis at the push of a button. Periodical or manually controlled evaluations can be compiled from the data base of the SR::xServer for the reporting.

Decreasing fuel costs and $CO_2$ costs //
Increasing the reliability and availability

# Condition and Process Quality Monitoring with SR::SPC and SR::EPOS

- Comprehensive recording of the actual state during the implementation
- Cost savings owing to tried and tested concept (analysis, assessment, optimization, projection)
- Economically efficient unit operation by identifying current potentials for optimization
- Reliable, automatic early detection of weak spots in the process
- Better predictive organization of maintenance measures

### Commercial and technical challenges

The change of the electricity market due to the energy turnaround is changing the requirements to conventional power plants. The strongly fluctuating feed of renewables requires a more flexible mode of operation of the conventional plants with an increasing number of start-ups and load changes in greater and greater ranges. As a result of the flexible mode of operation, the power plants today are subject to stronger stresses than in the past. The stresses, which make themselves felt e.g. in an increased wear and tear of the plant components, regularly lead to undetected deteriorations of the plant efficiency or to apparently sudden failures, often with significant economic consequences. The use of intelligent energy management systems lends itself to the prevention of such additional costs. By continuously evaluating existing performance values, these systems provide reliable information that allows for an optimized mode of operation and maintenance early on, helping to increase the availability of the plant.

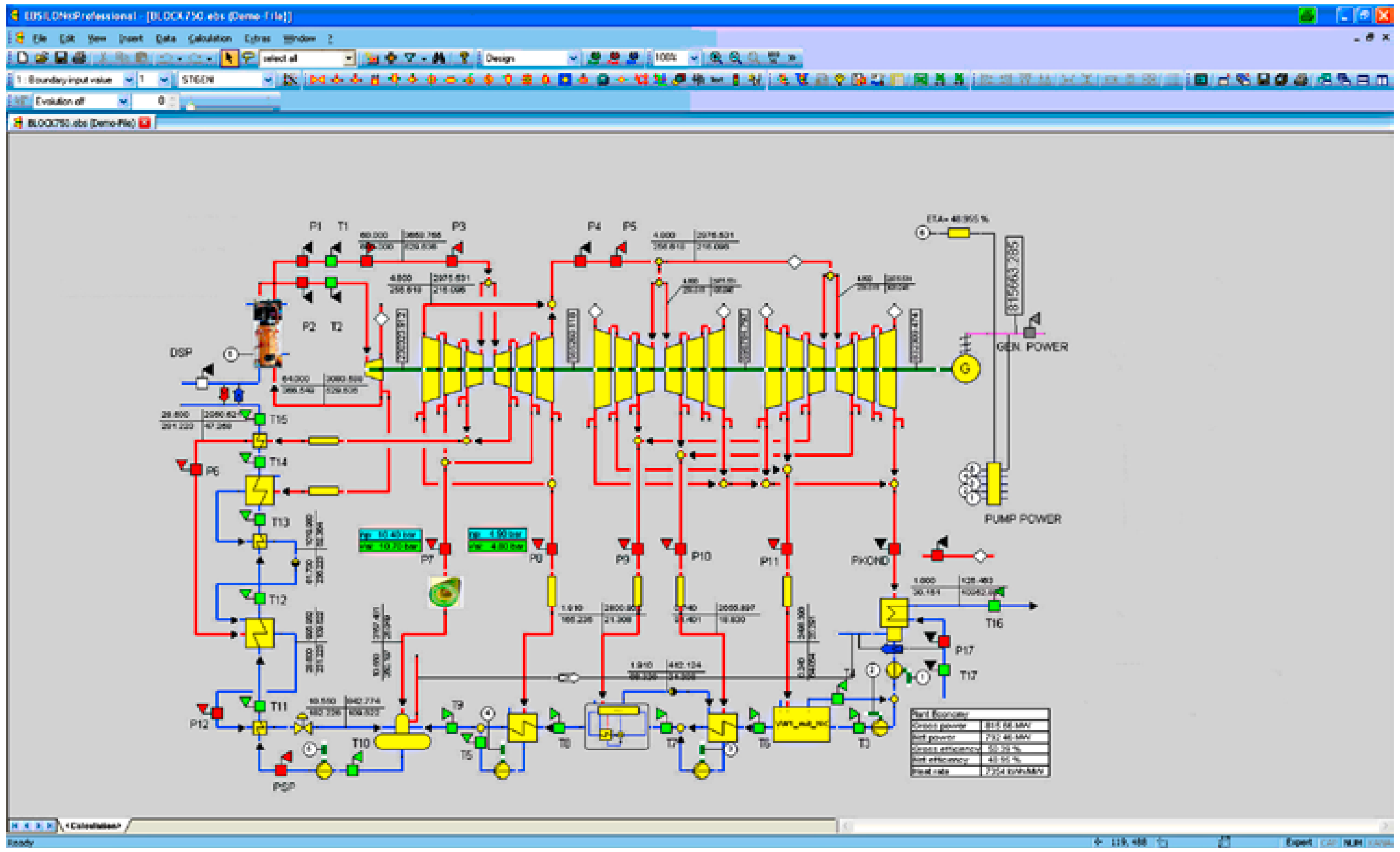
### Potentials for optimization in the mode of operation of the plant

### Online process quality monitoring

The continuous monitoring of the current process quality represents an essential possibility to exploit potentials for optimization in power plant operation. In practice, the deviation from the best possible plant performance achievable with unimpaired plant components often occurs creepingly and is mostly superimposed by the influence of external boundary conditions like e.g. load level or fuel- and environment-related influences and is thus hard to detect. The consequence is a sometimes significant deviation from the best possible efficiency that often remains undetected for a long time – also due to staff reductions.

With SR::EPOS, the power plant process is continuously monitored and assessed under technical and, where necessary, economic aspects. For this, important process

Visualization of the data in the process image and diagram



The reference value can be calculated by means of a thermodynamic cycle simulation (EBSILON® *Professional*)

and component characteristics like efficiencies, terminal temperature differences, heat rates, etc. are determined and summed up first. Subsequently, a performance factor is created by comparing the current characteristic with a reference value.

The required setpoint value is calculated online in each case, and always suiting the current mode of operation of the plant. Depending on the case of application, the setpoint value can be calculated by means of a thermodynamic cycle simulation (EBSILON®*Professional*) based on physical principles or by data-based models using neural networks (SR::SPC).

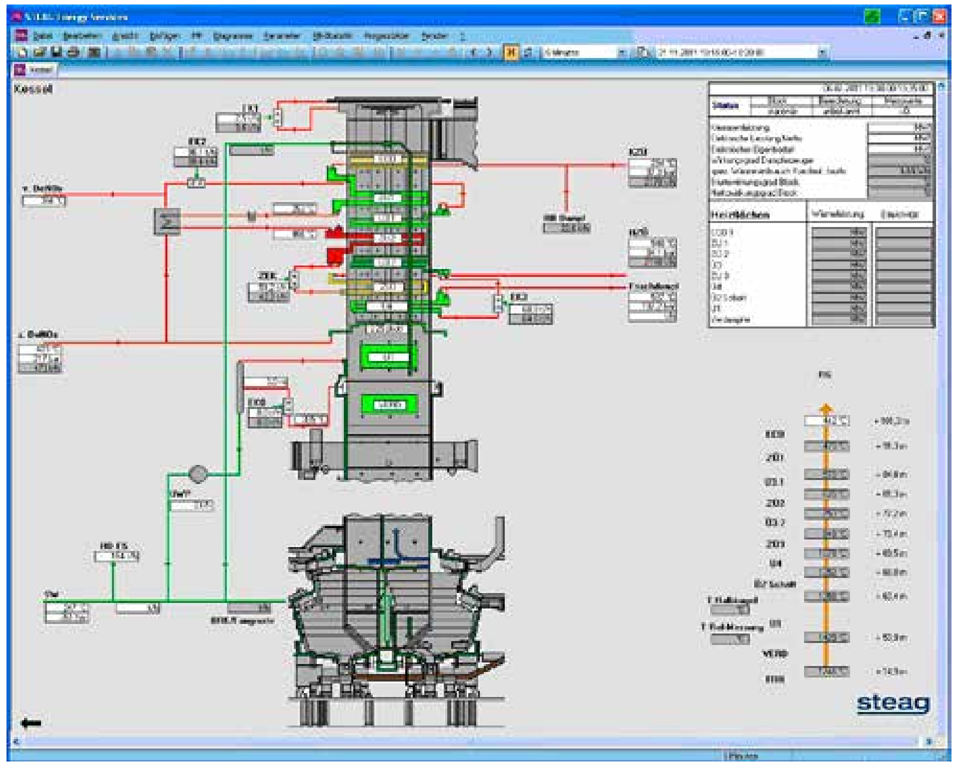
The results of the process quality monitoring are output online in process images and trend diagrams. The user is made aware of current deviations by means of color changes.

The process quality monitoring can be expanded in a modular way. The following additional modules are available:

- What-if module for process assessment (for deviations from the setpoint value, the incurred additional operational costs and the occurred additional heat consumption respectively are shown)
- Measured data reconciliation according to VDI 2048
- Determination of the modes of operation (allocation of the energy input to start-ups, steady-state condition, shutdown, …)
- Further ones if needed, e.g. min./max. module

### Online unit optimization

Another option for decreasing the operating costs consists in the best possible adjustment of the mode of operation of the plant to boundary conditions changed in the short-term. In the context of the energy turnaround and the required



Process image with detailed view of a boiler

transition to a flexible mode of operation of the plants, the unit optimization is becoming increasingly important.

Changes in the mode of operation can be simulated continuously and in an automated way by means of what-if calculations on the basis of the current performance values. Depending on the plant configuration and degrees of freedom in the mode of operation, an optimal mode of operation from an economic and ecological point of view can thus be suggested. Typical cases of application for the optimization of the mode of operation in conventional power plants are:

- Setting the optimal cooling water quantity
- Optimizing the use of the soot blowers
- Optimizing the mill operation

The required adjustment of the mode of operation can either be effected manually or closed loop according to the recommendations of the optimization calculation.

### Potentials for optimization in the mode of operation of the plant

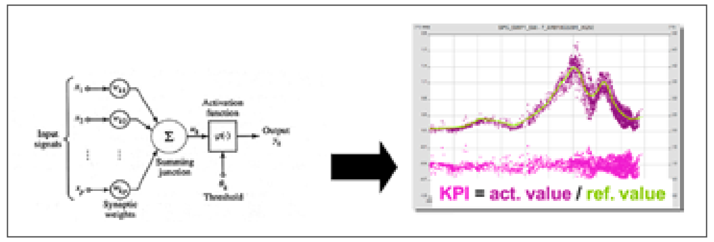
#### Online condition monitoring

A third important option to keep track of the potentials for optimization in the power plant is the automatic condition monitoring of vital power plant components. The operating behavior of the power plant components changes continuously due to wear and fouling. Again and again, these changes lead to failures. These failures appear to occur suddenly and without prior symptoms and, among others, have the following economic consequences:

- Missed profit due to unplanned downtimes
- Expensive additional purchase of external power in the case of non-disposable non-availability
- Increased costs of repair due to short-term planning

The use of data-based models by SR::SPC allows to monitor important performance values like e.g. vibration values, leakage quantities, or the number of control processes per time, which are indicators of change in a component condition. The advantage of data-based models is that these can also be created without detailed knowledge of the internal physical coherences and can therefore be put to multifaceted use.

For creating the model, a historical data record is "learned" by an artificial neural network. Here it is crucial that the selected data record shows the behavior of the unaffected component and that it contains the target variable (e.g. the vibration amplitude of a pump) as well as all vital influencing variables (e.g. rotation speed, flow rate, etc.). The trained network can then be systematically accessed to provide an appropriate setpoint value for the current mode of operation.



The setpoint value can be calculated data-based by means of neural networks



The setpoint value retrieved this way is consistent with the historical value of the unaffected component.

Deviations can be detected easily by comparing the actual value and the setpoint value. In the case of critical deviations that may indicate impending damages, the user can react early on and is often able to convert "non-disposable" into "disposable non-availabilities". The required repair work can be prepared and e.g. purposefully be scheduled for off-peak hours or weekend downtimes.

### Early warning system against damages and faults

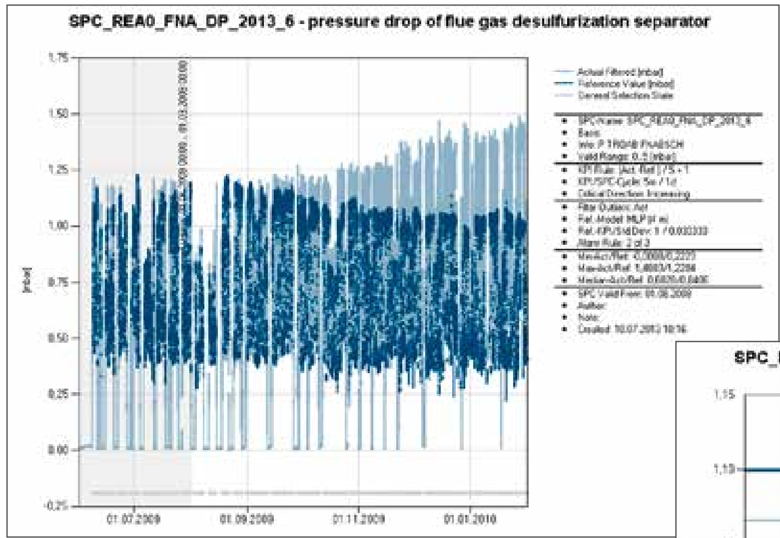
#### Statistical process control

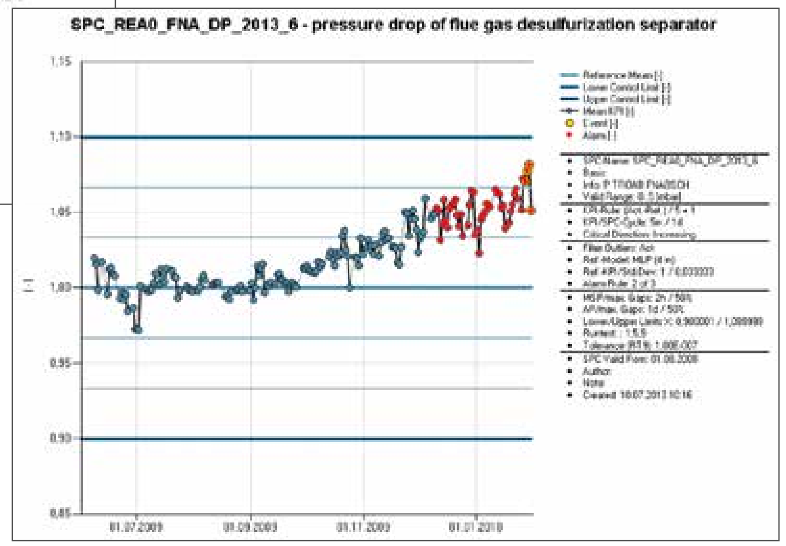
In the context of the process quality monitoring and condition monitoring introduced above, the setpoint values belonging to the current mode of operation are calculated for important measured values and characteristics in each case. By comparing the actual and setpoint values, standardized quality characteristics, so-called KPIs (key performance indicators) are calculated. These are independent of the mode of operation of the plant and the ambient conditions.

If an individual KPI deviates from a specified target value at a time of assessment, this is a first indication of an interference. If the deviation recurs or increases at later points in time, the indication of an interference intensifies.

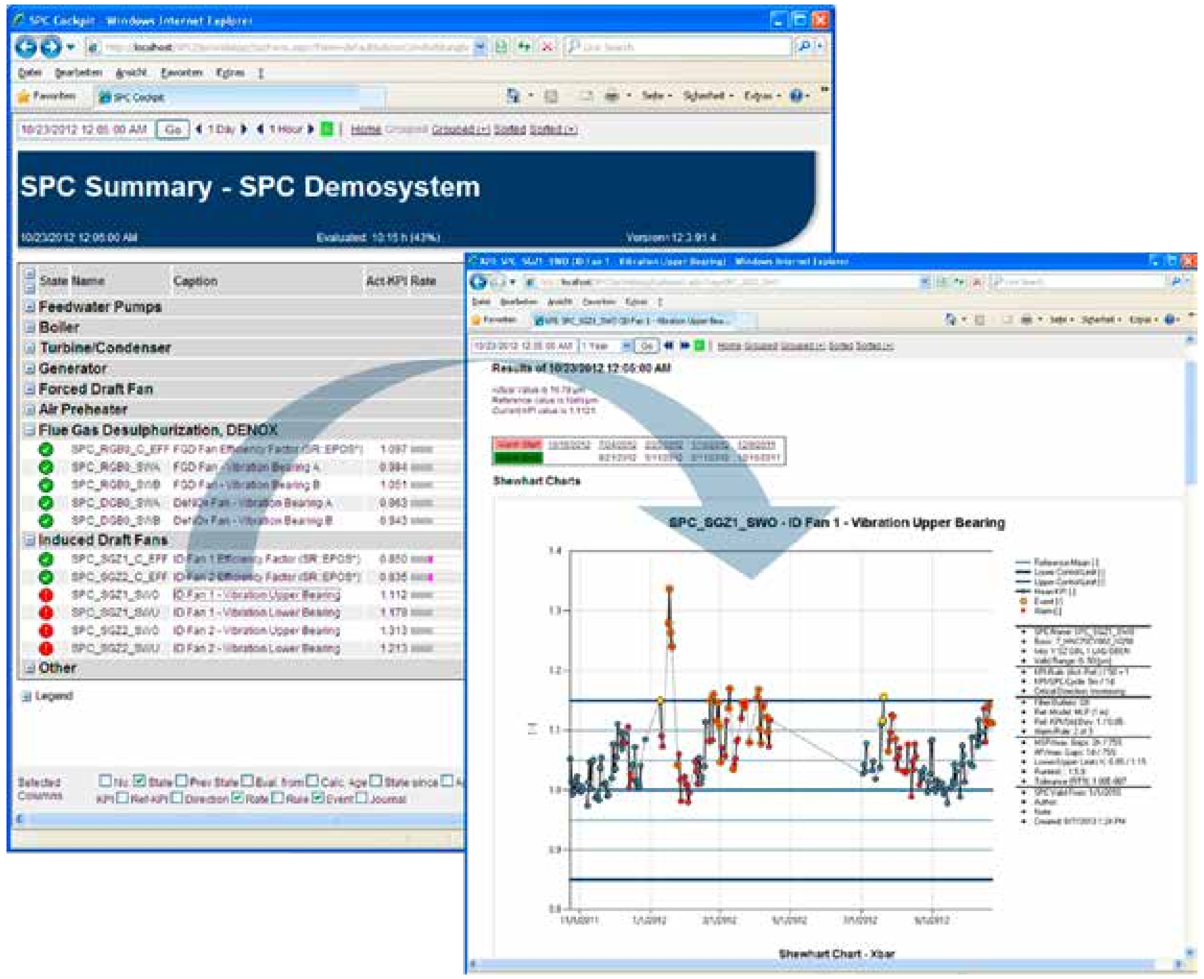
The chronological sequence of KPIs can be evaluated by means of methods of statistical process control (SPC). The SPC methodology has been developed to detect significant deviations of a process from a reference condition as early and reliably as possible.

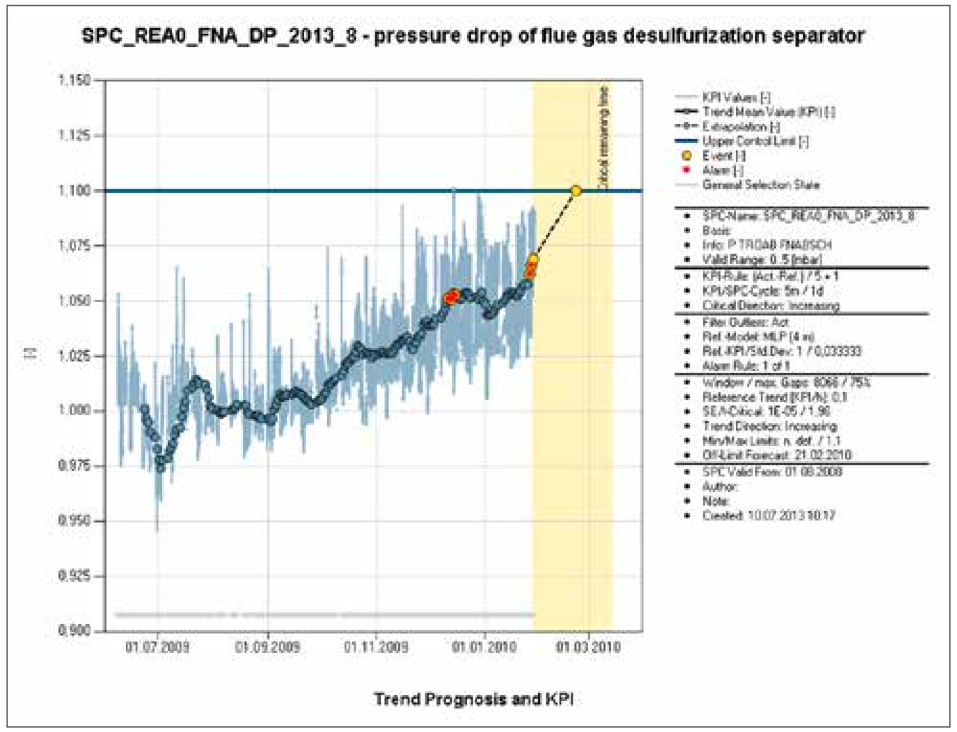
So-called control charts have been in use in production as tools for quality assurance for many years; they are also an important element of statistical process control. Control charts are diagrams that represent the chronological sequence of characteristic process parameters / KPIs in a clear way. This way, deviations from the expected behavior that indicate faults can be detected earlier and more reliably than in the case of an isolated contemplation of a single value.




**Above: Actual value and setpoint value showing increasingly critical behavior**
**Right: The SPC control chart detects the critical change of the KPI**




**SR::SPC Cockpit: Event center and automatic information by e-mail in the case of an event**

**SR::SPC projection feature: information on the future fouling behavior and the next point in time of a measure to be executed periodically**

KPI behaviors detected as critical are displayed to the user by SR::SPC in a web-capable overview (see the illustration top left) by corresponding color changes in a traffic light system. In the overview, all monitored KPIs of a site can be captured at a glance, so that with one brief look, the plant condition can be determined completely. With one click on the KPIs, the stored control charts can be activated and analyzed in detail. Moreover, in the case of conspicuous KPI behaviors, previously defined e-mail recipients will automatically be informed about the current condition with a brief log (see the illustration top right).

The SPC procedure particularly lends itself to monitoring the KPIs due to its high sensitivity and, at the same time, low proneness to false alarms. The continuous monitoring of the KPI behaviors significantly contributes to detecting impending damages or problems in an automated way. It is largely impossible to “miss” critical changes as the responsible persons are automatically informed about a fault (process quality monitoring) or warned of an impending damage (condition monitoring) by e-mail. They can quickly initiate measures for fault rectification or plan measures in terms of condition-based maintenance, significantly decreasing the additional costs that would otherwise incur.

With the optionally available module for trend recognition, components like e.g. an air preheater that are subject to wear or fouling during operation and require periodic cleaning and repair, respectively, can be monitored even better. For instance, the trend recognition can analyze the fouling gradient of an air preheater as a function of the operating hours and mode of operation, and issue a warning in the case of an increasing speed of fouling.

In addition, the projection feature can provide information on the future fouling behavior and thus estimate the next point in time of a measure to be executed periodically (see the illustration above).

Via the available interfaces (OPC), the system can be connected to any system by other manufacturers like e.g. turbine monitoring or lifetime monitoring etc. at will.

Homogenizing processes // Reducing additional fuels // Decreasing emissions

# Intelligent Combustion Control with the PIT Navigator

- Optimize the combustion process
- Homogenize the mode of operation and the furnace temperatures fully automatically and across shifts
- Increase the boiler efficiency or the waste throughput while complying with the limit values
- Use an automatic adjustment to changes in the fuel quality

### Commercial and technical challenges

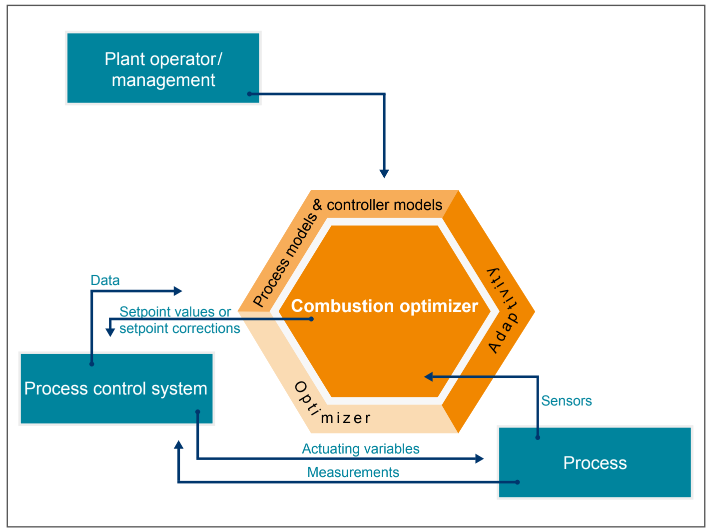
A high efficiency of the steam generator or increasing the throughput of a waste incineration plant belong to the essential economic goals of the respective operating companies.

To achieve these goals, the technical possibilities of the respective plants have to be used optimally. Among other things, this is achieved by homogenizing the plant operation; thus reduced fluctuations e.g. of the steam temperature allow to approach technical limits more closely.

This homogenization is effected by suitable optimization systems that directly engage with the DCS. To achieve this, however, conventional systems have to be manually adjusted again and again due to constantly changing process para-meters, mainly influenced by load, fuel, or time between overhauls.

### Combustion optimization by intelligent closed-loop control and optical sensors

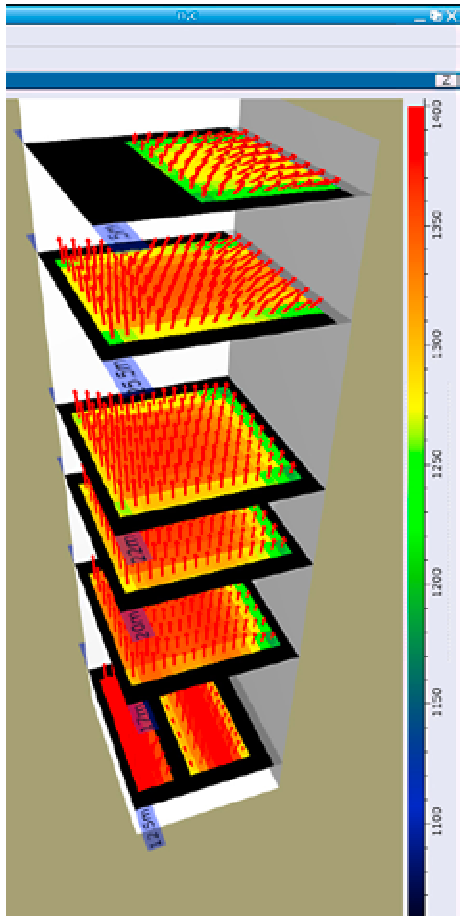
The combustion optimization by STEAG Powitec automatically adjusts to changing process parameters. The data from complementary sensors like heat flow sensors and furnace camera(s) serve as a basis for this intelligent closed-loop control. The data analysis is carried out automatically online and provides the temperature, intensity, position ignition line and center of combustion, flow, mixing, and movement in the furnace.

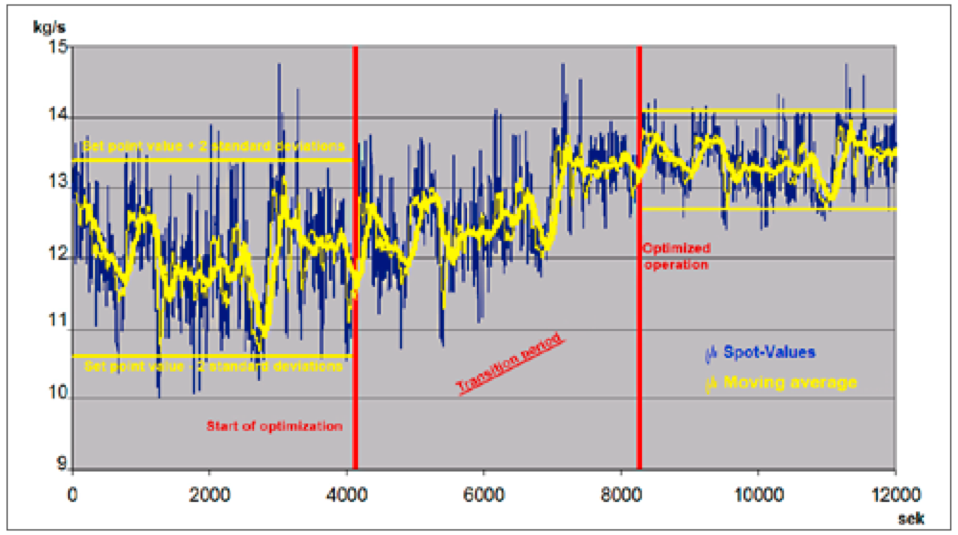



Overview: mode of operation, PiT Navigator

The constant collection and analysis of these data allows to achieve a closed-loop control of local air / fuel ratios that is adjusted to the current condition, faster, and thus more efficient.








Left: Online CFD in a waste-fired boiler with six horizontal sections for temperature display in different colors (temperature legend at the right margin) as well as a representation of the directions and velocities of the flue gas by the directions and lengths of the arrows

Above: Typical behavior of the steam output fluctuation in a waste incineration plant before and during connection of the PiT Navigator. In optimized plant operation, the smoother operation allows to raise the setpoint value for steam e.g. in order to increase to throughput.

In this closed control loop…

- fuel flows, flames, and flue gas flows are permanently analyzed
- the relevant process features are autonomously searched for and selected from the raw data
- the correlation of all process data and sensor data is constantly checked, and
- learned conditions are automatically saved – with the effect of permanent autonomous learning.

The self-learning, multi-dimensional and predictive controller by STEAG Powitec (PiT Navigator) adjusts to process changes – like the autopilot of an airplane – without further support from the outside. It helps provide the process control system with “eyes and ears” for the optimized combustion control, and thus the combustion with a smoother mode of operation.

### Convincing results

The intelligent combustion optimization with the PiT Navigator yields convincing results, paying itself off within less than two years:

- Homogenized temperatures
- Less steam fluctuations
- Significant reduction of the additional fuel
- Homogenization across shifts
- Faster reaction in the case of fuel-related fluctuations by means of online projection
- Permanently self-learning (automatically re-adjusting)
- Optimization goals can be changed by the customer at any time

Reliable compliance with the nitrogen oxide limits, keeping the consumption of reducing agent as low as possible

# 3D Temperature-Controlled SNCR Procedure

- Complement the existing SNCR with an addition that makes sense: 3D temperature analysis in combination with intelligent closed-loop control
- Ensure compliance with the new limit values for NOx slip and NH3 slip
- Profit from the system's self-adaptive tuning
- Reduce your consumption costs

### Commercial and technical challenges

The new requirements for compliance with the emission limits of nitrogen oxide pose yet another challenge to many operators of combustion plants.

The SNCR procedure has long been used successfully for removing the nitrogen oxides from the flue gas. At conventional SNCR plants, however, the reducing agent is often injected into the flue gas only on one level or alternatingly on several levels. So far it has only been possible to use few values as a data base for the closed-loop control of the injection of reducing agent. As a consequence, load changes, temperature imbalances, and NOx concentration distributions are detected too late if at all. This procedure in use at many plants leads to a higher consumption of reducing agent and most notably to a significantly higher NH3 slip.

### Method of operation of the 3D temperature-controlled SNCR procedure

The solution by STEAG Powitec allows to determine temperatures and flue gas velocities locally. This is achieved by the additional use of heat flux sensors, digital cameras, and a three-dimensional online temperature analysis. With the 3D temperature-controlled SNCR procedure by Powitec, the information thus additionally determined is transferred into a temperature and NOx projection. This allows to allocate to each SNCR lance the amount of reducing agent adjusted to the respective NOx and the local temperature. Also, flexible nozzle lances whose direction of injection can be automatically adjusted depending on the local temperature can be aligned optimally. NOx limits and NH3 limits are thus reliably complied with – with the reducing agent consumption as low as possible.

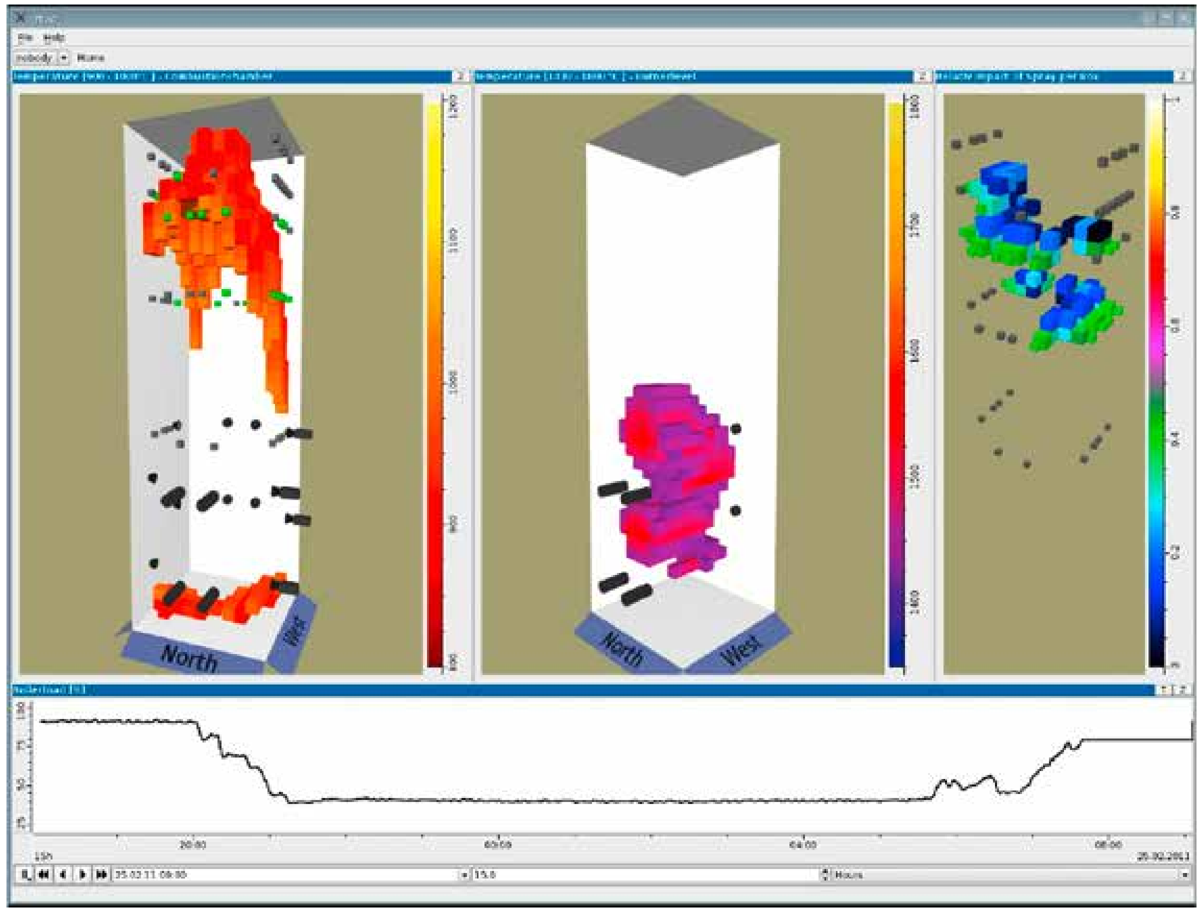
### Three-dimensional online temperature analysis

Different fuel properties or plant conditions permanently change the combustion, with the distribution of raw NOx values and flue gas temperatures changing locally as a result. A more comprehensive monitoring of the process by additional heat flux sensors and CCD camera(s) enables an early detection of the changes and thus an early reaction to these changes. Based on this, an online CFD (computational fluid dynamics) is compiled, which then calculates the temperature distribution that changes depending on load and current fuel properties. With the input parameters thus generated, an efficient and intelligent closed-loop control of the SNCR is enabled.

### Intelligent SNCR control – PiT Navigator SNCR

The self-learning and self-tuning STEAG Powitec controller (PiT Navigator SNCR) is based on a "non-linear model predictive control" (NMPC) and enables the multi-dimensional closed-loop control of complex processes. In contrast to conventional solutions where rules have to be manually adjusted to the process parameters like fuel properties,






**Screenshot of the online CFD from a 576 t/h steam boiler**

**Left: Display of the temperatures between 800 and 1,000 °C in the orange boxes. Active SNCR lances are shown as little green boxes, inactive ones as little gray boxes.**

**Center: Temperatures between 1,430 and 1,800 °C on the burner levels**

**Right: Relative effect of the ammonia spray in the cyan-colored and blue boxes**

**Bottom, across: Load behavior over 24 hours**

slagging, wear, etc. all the time, the PiT Navigator SNCR trains itself continuously. In this manner, it self-adaptively adjusts to process changes without any further external support.

### NOx soft sensor

The process model is also used for creating a permanent NOx projection (soft sensor). It supplies the PiT Navigator SNCR with the NOx values in the furnace, locally and chronologically prior to the NOx clean gas measurement. That way, this calculated NOx value supports the predictive closed-loop control.

### Useful addition to existing SNCRs

The STEAG Powitec upgrade package for plants with the possibility to activate individual nozzles typically comprises the following:

- Complementary process observation by additional heat flux sensors and CCD camera(s)
- Three-dimensional online temperature analysis "PiT Online CFD" for determining the local temperature and the flue gas velocities in the first draft
- Self-learning, self-tuning predictive SNCR closed-loop control "PiT Navigator" based on permanent NOx projection

### Overview of the benefits:

- Addition to existing SNCR plants or equipment along with new SNCR plants
- Reliable compliance with the new limit values (NOx/NH3)
- Autonomous and automatic adjustment of the system to changes, regardless whether depending on load, fuel, or time between overhauls
- Reduction of the consumption costs

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